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Impact of rib fixation on quality of life after major trauma with multiple rib fractures

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ABSTRACT

Introduction: Multiple rib fractures have been shown to reduce quality of life both in the short and long term. Treatment of rib fractures with operative fixation reduces ventilator requirements, intensive care unit stay, and pulmonary complications in flail chest patients but has not been shown to improve quality of life in comparative studies to date. We therefore wanted to analyse a large cohort of multiple fractured rib trauma patients to see if rib fixation improved their quality of life.
Methods: Retrospective review (January 2012 - April 2015) of prospectively collected data on 1482 consecutive major trauma patients admitted to The Alfred Hospital with rib fractures.
The main outcome measures were Quality of Life over 24 months post injury assessed using the Glasgow Outcome Scale Extended (GOSErate) and Short Form (SF12) health assessment forms and a pain questionnaire.
Results: 67 (4.5%) patients underwent rib fixation and were older, with a higher incidence of flail chest injury, and higher AIS and ISS scores than the remainder of the cohort. Rib fixation provided no benefit in pain, SF-12 or GOSErate scores over 24 months post injury.
Conclusions: This study has not been able to demonstrate any quality of life benefit of rib fixation over 24 months post injury in patients with major trauma.

Background

Fractured ribs are a common injury seen in trauma patients and are present in approximately 21% of patients admitted to trauma centres with blunt chest trauma [1]. At the most severe end of the spectrum of rib fracture injuries, flail chest is associated with life threatening injuries and a significant mortality [2]. Although older studies have reported an associated mortality of 33%, a more recent Canadian national database study showed a mortality of 16% [3]. Aside from the acute impact of rib fracture injury, longer term morbidity of pain, disability and deformity have been described [4,5]. Multiple rib fractures have been shown to have a significant and sustained impact on quality of life [6]. Over the last few years there has been increasing interest in operative rib fixation in flail chest and multiple fractured rib patients. Improvements in ventilation times, intensive care unit stay, pulmonary complications, tracheostomy rates, and chest tube requirements have been demonstrated in several small randomised controlled trials, and confirmed in multiple meta-analyses [7–12]. However, the impact of operative rib fixation on quality of life in these patients is much less compelling. In fact we were specifically unable to demonstrate any difference in quality of life as demonstrated by the short form 36 questionnaire in ventilator dependent flail chest patients undergoing rib fixation in a randomised controlled trial [7]. We therefore wanted to analyse a larger cohort of multiple fractured rib trauma patients from our centre to see if rib fixation improved their quality of life over the 24 months following their injury.

Methods

Quality of life data was collected from a consecutive cohort of patients from The Alfred hospital Australia. The Alfred Hospital is one of two adult major trauma services in the state of Victoria, Australia. Over 8000 injured patients are admitted to the Alfred each year with an overall mortality of 1.8%. Of these, 1400 are major

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trauma patients, with an overall mortality of 8.2%, including over 600 major chest trauma patients with a mortality of 5%. The Alfred hospital data was collected from the Alfred Trauma Registry– a prospective database on all trauma patients admitted to the hospital. All patients admitted to the hospital between January 2012 and April 2015 with major thoracic trauma (Abbreviated Injury Scale [AIS] $\geq$3) and a diagnosis of multiple fractured ribs were considered for inclusion in this cohort.

All ventilated patients with flail chest are considered for rib fixation in our institution, unless there is a contraindication to operate. Non ventilated patients are considered for rib fixation based on pain, displacement and non-invasive ventilator requirements. Non operative management protocols for rib fracture patients in our institution include management by a specialist pain team with a multimodality analgesia regimen which includes oral opiates, patient controlled intravenous opiate infusions, ketamine infusions, gamma amino butyric acid analogues, and non-steroidal anti-inflammatory drugs. Epidural or paravertebral infusions of local anaesthetic agents are also used. Physiotherapy input to address adequate chest expansion and patient mobilisation is also utilised.

Patients not classified as major trauma, or with a thoracic AIS < 3 were not included in this group. Follow up data was collected on the enrolled patients by the Victorian State Trauma Registry (VSTR). Institutional ethics approval was granted and the requirement for individual patient consent was waived. (Alfred Hospital Ethics Committee (EC00315) approval 399/11) Data is prospectively collected into the VSTR and Alfred Trauma databases with a retrospective opt out consent process in place. VSTR has ethics approval from all trauma receiving hospitals in the state and Alfred Hospital institutional ethics approval has been given for the collection of data in the Alfred Trauma Registry. Thus major trauma patients received by other regional hospitals and transferred to The Alfred were also included in this cohort.

VSTR data is collected by telephone interview with either the patient or by proxy. VSTR collects data about all major trauma patients in the state with major trauma being defined as any of:

1) death after injury;
2) an Injury Severity Score (ISS) >15;
3) an intensive care unit (ICU) stay > 24 h, requiring mechanical ventilation for at least part of their ICU stay;
4) urgent surgery for intrathoracic, intracranial, intra-abdominal procedures, or fixation of pelvic or spinal fractures [13].

VSTR does not collect data regarding patient comorbidities.

The survey instruments, administered at 6, 12 and 24 months post-injury, are the Glasgow Outcome Scale Extended (GOS-E), the twelve-item short form (SF-12) health survey, and a pain questionnaire using a numerical rating scale for pain ranging from 0 (no pain at all) to 10 (worst possible pain). The GOS-E provides a global measure of function taking into account domains such as social and leisure activities, relationships, return to work, self-care and mobility in the community, and is rated on a scale as follows:

1) Dead
2) Vegetative State
3) Lower Severe Disability (carer required for all activities of daily living)
4) Upper Severe Disability (able to look after themselves for up to 8 h per day but unable to perform tasks out of the house such as shopping without assistance)
5) Lower Moderate Disability (able to shop, drive or use public transport without assistance but unable to work or study, and rarely participates in social or leisure activites)
6) Upper Moderate Disability (able to shop, drive or use public transport without assistance and able to work or study but at a reduced capacity. Extensive restriction to social or leisure activities)
7) Lower Good Recovery (returned to preinjury work or study capacity but still reporting some disruption to social and leisure activities)
8) Upper Good Recovery (essentially no problems relating to their injury that affect daily life) [14].

For the purposes of analysis, GOS-E rates were dichotomised into good recovery (GOS-E rate 7–8) or disability (GOS-E rate $\leq$6) in accordance with our earlier report [6]. This serves to make the GOS-E result more clinically relevant. Follow up rates in the database have been reported as 86%, 83% and 82% for 6 months, 12 months and 24 months respectively [13]. The Abbreviated Injury Score 2008 version (AIS08) has been used in this dataset.

To further ensure balanced comparisons between operative fixation and non-fixation patients, a matched sensitivity analysis was conducted matching patients identically for their Abbreviated Injury Scale (AIS). The AIS describes type, location and severity of injury and is one of the most common anatomical-based scales currently used for traumatic injuries [15].

Statistical analysis

Baseline group comparisons were conducted using continuity corrected chi-square test for equal proportion (or Fisher's Exact tests where numbers were small), student t-tests for normally distributed data and Wilcoxon rank-sum tests otherwise with results presented as percentages(numbers), mean(standard deviation) or median (interquartile range) respectively. Longitudinal multivariable analysis was performed using mixed linear modelling with an unstructured covariance matrix fitting main effects for rib fixation, time and an interaction between the two to determine if rib fixation patients behaved differently over time. Results have been reported as least square means (95%CI) averaged over all time points with specific time points only reported if a significant interaction was present. To account for baseline imbalance between groups, multivariable analysis was performed adjusting for age, thoracic AIS, flail segment, mechanical ventilation and year of admission. Linearity assumptions for age were confirmed by dividing age into tertiles and treating as a categorical variable.

Sensitivity analysis was performed by identically matching controls to cases by type, location and severity of injury (AIS) at a ratio of 3:1. Univariable and multivariable longitudinal analyses were again performed using mixed linear modelling as previously described with the addition of matching strata included as a random effect. Covariates adjusted for were age, mechanical ventilation and year of admission. All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and a two sided p-value of 0.05 was used to indicate statistical significance.

Results

A total of 1482 consecutive major thoracic trauma patients (AIS $\geq$ 3) admitted to The Alfred hospital with multiple fractured ribs over the 40 month review period were identified. Demographic data on the 1482 is presented in Table 1. The rib fixation group were significantly older, with higher Abbreviated Injury Scale (AIS) thoracic and abdominal scores, higher overall AIS count, and higher ISS score (Table 1). The rib fixation group also had a much higher percentage of patients with a flail segment, and were more likely to have an associated abdominal injury. Contact success in the entire cohort at 6 months was 87%, 12 months 85% and 24 months 63%.

Table 1
Demographics.

Group Variable	Entire cohort N = 1482	No rib fixation N = 1415	Rib fixation N = 67	P value*
Age years, mean(std)	53.6 (19.2)	53.4 (19.2)	58.9 (17.2)	0.02
Male (number [%])	74.1% (1098)	74.0% (1047)	76.1% (51)	0.81
Abbreviated Injury Scale				
Thoracic	3 [3–3]	3 [3–3]	4 [3–4]	<0.0001
Head	0 [0-2]	0 [0-2]	0 [0-1]	0.24
Face	0 [0-0]	0 [0-0]	0 [0-0]	0.41
Neck	0 [0-0]	0 [0-0]	0 [0-0]	0.14
Spine	0 [0-2]	0 [0-2]	2 [0-2]	0.16
Abdominal	0 [0-1]	0 [0-1]	0 [0-2]	0.01
Upper Extremity	0 [0-2]	0 [0-2]	1 [0-2]	0.11
Lower Extremity	0 [0-2]	0 [0-2]	0 [0-2]	0.59
Flail segment	11.7% (173)	9.8% (138)	52.2% (35)	<0.0001
AIS count	6 [4–10]	6 [4–9]	8 [5–14]	0.002
ISS (AIS08)	17 [13–25]	17 [13–24]	24 [14-30]	0.002

* comparison of rib fixation patients vs non-rib fixation patients.

Outcome data is shown in Table 2. Univariate analysis showed that a much higher proportion of patients in the rib fixation group required invasive mechanical ventilation during their admission, required intensive care unit (ICU) admission and mechanical ventilation (MV) support for longer and were discharged to rehabilitation rather than home (Table 2).

Of the entire cohort, only 47% were working either full time or part time prior to the accident. At 6 months post accident, only 56% of that group had returned to work, with 58% at 12 months. Comparing the non fixation group to the fixation group, at 6 months, return to work rates were 374/665 (56%) vs 16/32 (50%) (p = 0.65) and at 12 months 387/665 (58%) vs 15/32 (47%) (p = 0.41).

Univariable longitudinal analysis showed significantly lower SF-12 PCS scores in the rib fixation cohort (mean (95%CI) 37.5 (34.1–41.0)vs 42.7 (41.9–43.4)p = 0.004) (Table 3). Following multivariable adjustment for imbalances between groups there were no overall differences in quality of life measures (Table 3).

Matched sensitivity analysis

59 of 67 (88%) rib fixation patients were able to be matched on AIS score at a ratio of 3:1. (Table 4). Despite matching patients identically for type, location and severity of injury, patients receiving rib fixation, remained older [58.6 (17.3) vs 51.9 (18.1) p = 0.01] and significantly more likely to require mechanical ventilation [58% vs 31% p = 0.0004] (Table 4). Multivariable longitudinal analysis over the 24 months following surgery, showed no significant differences between groups (Table 5).

Table 3
Longitudinal analysis: mean (95% CI).

Variable	No Rib Fixation	Rib Fixation	P-value[1]	P – interaction[2]
Univariate				
GOSE	5.8 (5.7 - 5.9)	5.4 (4.9 - 5.9)	0.12	0.91
Pain	2.0 (1.9 - 2.2)	2.2 (1.5 - 2.9)	0.64	0.55
SF MMC	51.6 (50.9 - 52.3)	51.9 (48.8 - 55.1)	0.84	0.48
SF PCS	42.7 (41.9 - 43.4)	37.5 (34.1 - 41.0)	0.004	0.23
Multivariate[3]				
GOSE	5.5 (5.2 - 5.7)	5.7 (5.2 - 6.1)	0.38	0.92
Pain	2.3 (2.0 - 2.7)	2.2 (1.4 - 2.9)	0.70	0.58
SF MMC	51.5 (49.9 - 53.0)	52.0 (48.9 - 55.2)	0.75	0.57
SF PCS	41.1 (39.4 - 42.7)	38.7 (35.2 - 42.1)	0.20	0.21

[1]Global comparison of rib fixation vs no rib fixation across all 3 time points.
[2]P-value for interaction between rib fixation and time.
[3]Adjusted for age, year of admission, Abbreviated Injury Score count, flail & mechanical ventilation.

Discussion

We have previously shown that multiple fractured rib injuries are associated with reduced quality of life which does not return to normal in a large proportion of patients by 24 months [6]. This has been confirmed by others who have also demonstrated chronic pain and reduced quality of life in rib fracture patients [16–19]. In the past decade, there has been increasing interest in the use of surgical rib fixation to improve short and long term outcomes of rib fracture patients, and particularly in patients with ventilator dependent flail chest injury. The evidence for improvements in MV time, ICU LOS, respiratory complications such as pneumonia and need for tracheostomy, and reduction in hospital costs with rib fixation are now quite compelling [7–12]. The impact of rib fixation on QoL is less clear. In a prospective randomised controlled trial of rib fixation versus non operative management in flail chest patients from our institution, we were unable to demonstrate any improvements in QoL in the operative group [7].

Table 2
Outcome data.

	Entire cohort (n = 1482)	No rib fixation (n = 1415)	Rib fixation (n = 67)	P value*
Mortality	2.1% (31)	2.1% (30)	1.5% (1)	0.80
Invasive MV	25.2% (374)	23.5% (333)	61.2% (41)	<0.0001
MV duration (hrs)	93 [35-200]	89 [33-187]	157 [98-309]	<0.0001
ICU admission	46.3% (686)	44.9% (636)	74.6% (50)	<0.001
ICU stay (hrs)	184 [108-318]	173[103-309]	251[183-423]	0.001
Discharge destination				0.06
Home	50.6% (750)	51.2% (725)	37.3% (25)	
Rehabilitation	45.6% (676)	44.9% (636)	59.7% (40)	
Other	3.8% (56)	3.8% (54)	3.0% (2)	
Any Pain 6 months	49.2% (413/840)	48.9% (391/800)	55.0% (22/40)	0.55
Any Pain 12 months	43.1% (308/715)	43.1% (292/677)	42.1% (16/38)	1.00
Any Pain 24 months	43.4% (200/461)	42.9% (191/445)	56.3% (9/16)	0.42
GOSE 7 or 8 6 months	35.3% (414/1174)	35.9% (401/1118)	23.2% (13/56)	0.07
GOSE 7 or 8 12 months	37.3% (421/1129)	37.8% (406/1074)	27.3% (15/55)	0.15
GOSE 7 or 8 24 months	37.9% (314/828)	38.1% (304/798)	33.3% (10/30)	0.74

* comparison of rib fixation patients vs non-rib fixation patients.

Table 4
Matched sensitivity analysis.

Variable	Entire cohort (n = 236)	No rib fixation (n = 177)	Rib fixation (n = 59)	P value
Demographics				
Age years, mean (std)	53.6 (18.1)	51.9 (18.1)	58.6 (17.3)	0.01
Sex Male (number [%])	80.1% (189)	81.4% (144)	76.3% (45)	0.51
Abbreviated Injury Scale				
Thoracic	3 [3–4]	3 [3–4]	3 [3–4]	1.00
Head	0 [0-2]	0 [0-2]	0 [0-1]	0.02
Face	0 [0-0]	0 [0-0]	0 [0-0]	0.36
Neck	0 [0-0]	0 [0-0]	0 [0-0]	0.10
Spine	0 [0-2]	0 [0-2]	2 [0-2]	0.82
Abdominal	0 [0-2]	0 [0-1]	0 [0-2]	0.61
Upper Extremity	1 [0-2]	1 [0-2]	1 [0-2]	0.76
Lower Extremity	0 [0-2]	0 [0-1]	0 [0-2]	0.38
Flail segment	49.2% (116)	49.2% (87)	49.2% (29)	1.00
AIS count	7 [4–11]	7 [4–11]	7 [5–13]	0.61
ISS (AIS08)	23.4 (12.5)	23.7 (13.1)	22.5 (10.2)	0.51
Outcomes				
Mortality	0.8% (2)	0.6% (1)	1.7% (1)	0.44
Invasive MV	37.3% (88)	30.5% (54)	57.6% (34)	0.0004
Duration of ventilation (hrs)	137 [69-271]	114 [42-248]	153 [84-298]	0.30
Discharge destination				0.15
Home	51.7% (122)	55.4% (98)	40.7% (24)	
Rehabilitation	45.8% (108)	42.4% (75)	55.9% (33)	
Other	2.5% (6)	2.3% (4)	3.4% (2)	
Any Pain 6 months	49.2% (65/132)	47.4% (46/97)	54.3% (19/35)	0.62
Any Pain 12 months	42.5% (57/134)	42.6% (43/101)	42.4% (14/33)	1.00
Any Pain 24 months	47.4% (46/97)	46.4% (39/84)	53.8% (7/13)	0.84
GOSE 7or8 6 months	37.1% (73/197)	41.2% (61/148)	24.5% (12/49)	0.05
GOSE 7or8 12 months	38.3% (75/196)	41.2% (61/148)	29.2% (14/48)	0.19
GOSE 7or8 24 months	37.3% (62/166)	37.3% (53/142)	37.5% (9/24)	1.00

Table 5
Matched groups - longitudinal analysis: mean (95% CI).

Variable	No Rib Fixation	Rib Fixation	P-value[1]	P – interaction[2]
Univariate				
GOSE	6.0 (5.7 - 6.2)	5.5 (5.1 – 6.0)	0.09	0.93
Pain	2.2 (1.8 - 2.7)	2.1 (1.2 - 2.9)	0.76	0.85
SF MMC	51.9 (50.1 - 53.6)	52.5 (49.3 - 55.7)	0.73	0.48
SF PCS	42.2 (40.3 - 44.1)	38.4 (34.9 – 42.0)	0.07	0.18
Multivariate[3]				
GOSE	5.4 (4.9 - 5.9)	5.7 (5.2 - 6.2)	0.37	0.95
Pain	2.2 (1.3 - 3.2)	2.4 (1.4 - 3.4)	0.76	0.84
SF MMC	51.3 (47.7 - 54.8)	52.0 (48.3 - 55.8)	0.72	0.68
SF PCS	38.5 (34.3 - 42.7)	36.3 (32.0 - 40.6)	0.39	0.19

[1]Global comparison of rib fixation vs no rib fixation across all 3 time points.
[2]P-value for interaction between rib fixation and time.
[3]Adjusted for age, year of admission & mechanical ventilation.

In the current study, we found that our rib fixation group were older, with higher AIS and ISS scores, and had a larger proportion of flail chest injury than the remainder of the cohort. They also were more likely to be admitted to the intensive care unit, and required more mechanical ventilation, although the proportion of preoperative versus post operative ventilation has not been separated in this dataset. However, even after correcting for these group differences, we were not able to show an improvement in quality of life in the rib fixation cohort in any parameter measured. In fact they tended to have worse QoL as measured by the SF12 PCS. Our rib fixation cohort was small (only 67 patients), and reflects less than 50% of our surgical rib fixation patients over that time period. The remainder of our rib fixation patients either did not fulfil the criteria of 'major trauma' or had an AIS < 3 and so were excluded from this dataset.

Part of the reason we haven't shown improvements in QoL with rib fixation in this cohort, is that there are likely to be differences in the rib fracture injuries which have not been picked up in the broad measurements we have used to group patients. For example, in this study we have not collected data on the actual rib fracture injuries in terms of number of ribs fractured, bilateral or unilateral fractures or degree of displacement of fractures. These aspects would undoubtedly influence the decision to operate, and it is possible that the rib fixation cohort were identified clinically as being a higher risk group and therefore offered rib fixation.

Our decision making for rib fixation is individual. There are cases where there may be only one or two rib fractures that are very displaced, or a patient has an injury with AIS < 3 but a lot of pain, and these patients will be offered rib fixation in our institution. We are currently running a randomised controlled trial of rib fixation in non-ventilated patients with rib fractures to determine QOL outcomes in this subgroup and some of these patients will have an AIS < 3.

We tried to keep only the more severe thoracic injuries in our cohort for analysis by including only thoracic AIS ≥ 3. The definition of AIS 3 is ≥ 4 rib fractures or 2–3 rib fractures with haemothorax or pneumothorax, so this defined the least severe end of the spectrum for our cohort.

Other investigators have tried to correlate rib fracture pattern and severity with outcomes.

Dhillon et al., found that increasing number of fractured ribs was associated with worsening SF-36 PCS and Bodily Pain Score [18]. Furthermore, the location of the fractured ribs was relevant. Upper and lower rib fractures were associated with worse SF-36 scores than middle rib fractures. The most statistically significant results were the association of upper rib fractures with worse pain, and of lower rib fractures with worse dyspnoea burden.

Bugaev et al., identified that the degree of displacement of rib fractures, and the number of rib fractures predicted opioid

requirements in the acute setting [19]. Furthermore, they were able to quantify this, with each rib fracture increasing opioid requirement by more than 10%. Another study has shown that it is the rib fracture patients' perception of pain in the acute period (as measured by a Present Pain Intensity Scale) that predicts chronic pain, rather than number of rib fractures, bilaterality of rib fractures or injury severity score [17].

Although there are now quite a number of studies outlining the impact of rib fracture injuries on pain and quality of life outcomes, there is very little good quality data demonstrating a positive impact of rib fixation on these outcomes. Recent studies which have examined quality of life outcomes after rib fixation have been flawed in that there has been no comparison group [20–22], patients have chosen their own treatment group [23], or groups have not been historically comparable [24]. A recent systematic review concluded that no recommendation for rib ORIF for pain control could be made with currently available data [10]. The authors also concluded that no recommendation could be made for any outcomes in patients with non flail chest injury, with currently available data.

A recent comparative study also found no quality of life benefits in the surgical fixation group when compared to modern multidisciplinary treatment protocols [25]. However, that study was also flawed in that it was very small (19 surgical patients) with a historical control group, and significantly lower response rate to the quality of life questionnaire in the control group (47% vs 85%).

The incidence of 4.5% of surgical rib fixation in our entire cohort seems very low. However, it is almost exactly the same as that seen in a recent database study from the United States of 4.36% over 2007 to 2014 [26]. Although this penetrance of rib fixation is low, perhaps it is largely appropriate for the clinical injuries seen, and with the currently available evidence in mind. In our study, 20% of all flail chest patients had rib fixation. This is higher than the US study in which 14.5% of flail chest patients had rib fixation.

We did not find an increased return to work rate in the rib fixation cohort in this study. In both treatment groups, return to work rates did not appreciably increase between 6 and 12 months, a pattern we have previously identified in a similar cohort of patients [6]. It has been previously shown that rib fracture patients lose an average of 70 days of work or usual activity in the post injury phase [5]. However, in both this study and our previous study, patients remain off work for significantly longer periods than that. Perhaps it is the overall severity of the injuries in our cohorts which dictates a longer period off work. Interestingly, patient appraisal of injury severity has been found to be more predictive of time off work than objective measures of severity [11].

The association of acute rib fracture injuries with chronic pain, disability and reduced quality of life is indisputable [6,16,17]. However, identifying the exact predictors of these outcomes and trying to modify the outcomes is proving difficult. Retrospective studies will always be hampered by the differences in clinical decision making which impact on outcomes, but are difficult to identify or quantify in a study unless collected prospectively. This study serves as a reminder that there is currently minimal evidence that rib fixation improves long term quality of life in rib fracture patients.

Limitations

This is a single institution paper and a retrospective review, although the data is collected prospectively. We have tried to account for the inherent differences between groups with statistical analyses, but there are clinical details which are not collected in the VSTR database, which could be relevant to the outcomes we have assessed. A prospective randomised trial would be required to adequately address these differences. Less than 5% of the overall cohort underwent rib fixation. Our rib fixation cohort was small (only 67 patients), and reflects less than 50% of our surgical rib fixation patients over that time period. This highlights the selective application of this therapy for which the most appropriate indications are still being assessed.

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Conflicts ofInterest

SFM discloses lecture fees paid by Johnson and Johnson. The co-Authors have no other conflicts of interest to declare

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